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SNPO REVIEW
of the
REON SAFETY PROGRAM
for
CONTRACT YEAR 1964

NERVA NON-NUCLEAR TEST FACILITIES
LIQUID ROCKET OPERATIONS
AEROJET-GENERAL CORPORATION
SACRAMENTO PLANT

18 and 19 JANUARY 1965

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NERVA NON-NUCLEAR TEST FACILITIES

I. Introduction

Consistent with the requirement to design, develop, and test the NERVA turbopump, nozzle, cold flow development test systems and components, the NERVA Non-Nuclear Test Facilities have been or are currently being constructed to serve the NERVA Engine Development Program. Specifically, three primary testing zones within the Liquid Rocket Operations Test Area have significant NERVA Test Facility installations; Test Zone C, Test Stands C-6 and C-7; Test Zone H, Test Stands H-4, H-4A, H-5, and H-6; and Test Zone A Cryogenics Laboratory. The test positions within each test zone have been designed to serve specific requirements of the NERVA Non-Nuclear Test Program. Special Test Equipment and Facilities associated with each test position was carefully analyzed and designed to provide optimum performance of test hardware and maximum flexibility to the changing requirements of an R&D program. Also, where unique Special Test Equipment was required to meet special technical objectives of the program, small scale testing and computer analysis were conducted to insure proper selection of supporting equipment. Selection of Special Test Equipment components, such as valves, regulators, filters, and other support equipment were carefully analyzed and selected to insure the greatest degree of performance and reliability.

II. Test Zone C, Test Stands C-6 and C-7

Test Stand C-6 has been utilized extensively over the past three and a half years to conduct NERVA nozzle and NRX-A cold flow assembly testing. During contract year 1962, Test Stand C-6 underwent major modifications to accommodate NERVA nozzle hardware. Specifically, the overhead LH₂ run vessel was elevated to accommodate installation of a supersonic diffuser for altitude simulation to 60,000 feet. Final checkout and activation of the modified altitude test position was completed in January 1963, however, the original plan to install the diffuser was subsequently changed due to the inability of the contractor to complete the diffuser

as scheduled, and due to a revision in the technical objectives of the NERVA nozzle development program. In lieu of the installation of the diffuser, minor modifications to the test position were then accomplished to allow resumption of nozzle testing at sea level conditions. The diffuser was subsequently completed and will be installed as the program requires. Special Test Equipment serving this test position includes a 2910 gallon, 1235 psig, double wall, foam insulated LH_2 propellant supply vessel and a 2200 gallon, 1325 psig, uninsulated LO_2 propellant supply vessel. Durations of approximately 20 seconds, at a nominal flow rate of 70#/sec. can be obtained.

Test Stand C-6 was further modified to accommodate the NRX-A cold flow test system. Specifically, propellant piping systems, work platforms, and the installation of a 24" cold gas carry-off duct were installed. This installation was completed in September 1963.

Control Room C-2 provides instrumentation and controls capability for both nozzle and NRX-A test programs on Test Stand C-6.

Test Stand C-7, an adjunct to C-6, has been utilized since the fall of 1961 to conduct the NERVA Turbopump Development Program. The propellant for the TPA is supplied from a 14,000 gallon, 100 psig, vacuum insulated LH_2 vessel through an 8" vacuum jacketed line. Incorporated in the TPA suction line is a 250 gallon, 125 psig, dry insulated TSOV vessel for the purpose of minimizing the LH_2 TPA inlet velocity effect in order to improve the accuracy of the pump suction pressure and temperature measurements. The TPA turbine exhaust is carried through a 12" line designed to a maximum of 50 psia back pressure.

The LH_2 discharged from the TPA during the test is ducted through approximately 200 feet of 8" uninsulated line to a flare stack. Control Room C-2, serving the C-4, 5, 6 complex, also provides the necessary instrumentation and controls capability for the NERVA turbopump testing conducted on Test Stand C-7.

III. Test Zone H, Test Stands H-4, H-4A, H-5 and H-6

During Contract Years 1962 and 1963, Test Stands H-4, H-4A, H-5 and H-6 were constructed to serve as the primary NERVA Engine Non-Nuclear Test Facilities. The facility provided includes all the mechanical, instrumentation, and electrical controls equipment necessary to conduct hardware development test programs for the NERVA turbopump, nozzle (at sea level and altitude environments), cold flow development test system, and turbine power control valve test system. Specifically, Test Stand H-4 will be utilized to conduct NERVA nozzle tests at sea level and altitude environments. A water cooled tubular constructed supersonic diffuser with a L/D ratio of 6.7 can be utilized to simulate altitudes up to 60,000 feet. Water coolant being supplied to the diffuser at a rate of 500 GPM and 100 psig. A 14,000 gallon, 1800 psig, vacuum jacketed LH_2 run vessel and a 5000 gallon, 1800 psig, LO_2 run vessel provide propellants to the test hardware. Durations of 100 seconds at a nominal flow of 70#/sec LH_2 can be obtained.

Test Stand H-4A will be utilized to conduct the turbine power control valve (TPCV) test program. This facility has been provided with the capability to conduct these tests, utilizing heated hydrogen at 1350°F and 900 psig as the flowing fluid. Durations up to 600 seconds can be attained at maximum flows of 10#/sec.

Test Stand H-5 will be utilized to conduct the cold flow development test system development program. To simulate specified negative back pressures at the main nozzle and turbine exhaust exit planes, two stage ejectors are being provided. An overhead 105,000 gallon, 100 psig, LH_2 vacuum jacketed propellant vessel will supply propellant to the test hardware. Although this test position is currently planned for use on the CPDTS, the capability to conduct engine tests has been included, durations of 600 seconds can be attained.

Test Stand H-6 will be utilized to conduct the NERVA turbopump development test program. A 105,000 gallon, 100 psig vacuum jacketed propellant supply systems with 8" flowmeter will be utilized to supply the turbopump. Also, the

propellant suction system will incorporate a 250 gallon vacuum jacketed plenum chamber. A hydrogen heat exchanger capable of conditioning GH_2 to temperatures up to 1350°F at pressures of 900 psig and flows up to 10#/sec will be available to supply the necessary turbine motive fluid. The turbopump discharges into a 100,000 gallon, 75 psig catch vessel through an 8" vacuum jacketed propellant piping system. The turbopump turbine discharges through a parallel 10" exhaust system designed to a maximum back pressure of 50 psia. The NERVA TPA LH_2 run vessel also incorporates a remote tank weight measurement system. This system suspends the tank from a single point and measures the load with a high accuracy strain gage transducer. Since any electronic or mechanical system must be periodically checked, a dead weight calibrator is incorporated into the design using a simple beam balance and pivot flexures.

This system uses a Baldwin ULXXA load cell as a transducer and is attached to the suspension rod by use of a flexure on each side of the load cell to minimize any moment effects created by misalignment or deflections. A yoke is provided in the measuring system to attach the calibration beam to the load cell. Since there will be a small amount of horizontal translation of the inner run tank during the test run a flexure is required between the tank and the suspension rod. The upper flexure is attached to the support rod which is suspended from an "A" frame support. The upper attaching assembly is adjustable in vertical and horizontal direction to allow for proper alignment and elevation.

As the LH_2 is used from the tank a strip chart or digital type recorder will indicate the weight of LH_2 remaining in the tank at any time.

The overall accuracy of the system should be in the order of .25 percent of the measured weight. It should be pointed out that some items that effect the accuracy cannot be evaluated such as velocity effects at the outlet nozzles and the effects of manufacturing and installation errors creating misalignment and spring constants greater than calculations indicated. In many cases errors may be compensating

rather than additive; therefore, the accuracy will be outlined by systems. The total system accuracy should be somewhere between $+0.363$ percent and -0.377 percent of the total load. The minimum probable error for a single measurement is $.065$ percent.

The Instrumentation system is capable of measuring pressure, strain, temperature, flow rate, turbine speed, valve position, switch position, vibration, acceleration, time event and liquid level. The transducers employed are: (1) metallic and semi-conductor, four-arm, bonded strain gage, (2) metallic strain patches, (3) copper/constantan and chromel/alumel thermocouples, (4) platinum resistance temperature transmitters, (5) turbine-type flowmeters, (6) magnetic reluctance sensors, (7) resistance potentiometers, (8) micro switches, (9) piezo electric accelerometers, and (10) capacitance sensors. The transducers are standardized for each type of measurement to minimize the number of different configurations required of a basic signal conditioning unit.

The signal conditioning units consists of a combination of excitation sources, circuit completion components, simulation sources, ranging circuits, signal converters and amplifiers. The excitation sources are constant voltage and constant current power supplies. Circuit completion components are used to condition an analogous electrical output into a recordable voltage. Simulation sources are precision frequency generators and precision DC voltage sources used to range recorders for the desired measurement range. Ranging circuits produce a known signal from the transducer by creating the same effect a known physical condition would have on the transducer. These circuits are also used in ranging recorders. Frequency to DC convertors are used on the flows and speed systems to make the signal compatible with DC recorders. Because the majority of transducer outputs are low level (millivolts) single-ended or differential, wide-band, variable gain amplifiers are used prior to recording on a high level (volts) recorder.

Recorders available are divided into two basic groups. Analog and digital. The analog recorders are strip chart recorders, oscillographs, analog tape recorders, visual gages and time event recorders. The digital system is the analog-to-digital converter (ADC) and digital tape recorder. The ADC system is the primary source of data. The system sampling rate is 1200 s/s and channel capability is 300 channels. All channels are high level (C-Area). Because of the sampling rate per channel, low pass filters are employed to minimize folding errors. The recorded data, therefore, is considered steady state. The strip chart is a low response (cps) recorder. It is used primarily for viewing of prime and "kill" parameters during the test. The oscillograph is used to record low and medium frequency parameters. The analog tape recorder is used to record high frequency parameters. Visual gages are used for viewing of test stand parameters during a test which are not prime parameters. Time event recorders are used to measure time between events during a test.

In order to increase the flexibility of the recording units a patch panel is used. This patch panel enables the recording of any parameter on any type or number of recorders.

Although the instrumentation system is basically the same in H-Area as in C-Area, the equipment represents the latest advancements in the state-of-art. The major difference being in the ADC analog to digital recorder and digital tape recorder which is the primary source of data. The maximum system sampling rate is 10,000 s/s and channel capability is 192 channels. The system is capable of recording low level voltages, high level voltages, frequency and time interval. The sampling rate per channel is programmable. It can accept and record playback from an analog tape. The analog tape recorder is used to record high frequency parameters. It is capable of replaying data into the digital system at a speed slower than recording speed.

Each control room is also equipped with a three camera, closed circuit television system used for visually monitoring the test and the facility. An H₂

leak detection system is also provided in each area with monitors within the control rooms.

IV. Test Zone A, Cryogenics Laboratory

The Cryogenics Laboratory was activated in February 1963 and has since been utilized for a variety of NERVA component testing requirements. The NERVA portion of the main building and test bays was completed first for the NERVA program with additional capability added for NASA M-1 program utilization. The completed facility is now integrated with the total laboratory capabilities available to both programs. Included in these capabilities are twelve individual test bays provided to serve a wide range of component test requirements. In addition, three materials test bays for metallic and non-metallic materials evaluation in a cryogenic environment are located at the south end of the laboratory. The capabilities of the data acquisition center for the laboratory include signal conditioning equipment, recorders, a 96 channel analog to digital converter system and necessary patch systems.

Among the more significant activities carried out in the Cryogenics Laboratory is included the NERVA TPA bearing development testing. Bay 5 and Bay 9 are equipped for bearing test arrangements. A 50 HP MG set provides the necessary 440 V, 400 cycle bearing tester power to both of these bays. Bay 5 is served from a 450 gallon vacuum jacketed LH_2 run tank with Bay 9 served from a similar tank with 1000 gallon LH_2 capacity. Test conditions required and provided are 205 psig bearing tester discharge pressure at -400°F and at a nominal flow rate of 20 gpm. Bearing loads both radial and axial are applied pneumatically with high pressure gaseous hydrogen. Necessary instrumentation and controls are provided through a bay box located with the test bay.

A new phase of activity involving NERVA pump impeller spin and burst testing will be initiated in **January**. Portions of the new STE being provided for these tests include a GN_2 driven turbine capable of 60,000 rpm, combined with a special slip ring assembly to be installed in the spin pit facility of the laboratory.

The NERVA testing performed in the Cryogenics Laboratory since activation in February 1963 includes bearings, seals, valves and nozzle simulators. Extensive NERVA testing of a wide variety was planned during CY 64, however, program redirection in January 1964 produced a severe cut-back in testing requirements. During CY 1965 continued and renewed utilization is planned for testing bearings, pump impellers, TPCV's, the pressure vessel seal, and the upper thrust structure.

REON
SAFETY PROGRAM REVIEW
FOR CONTRACT YEAR 1964

Photo No.

Description of Photo

- C 1164 133 View of Testing Complex H-4, H-4A, H-5 and H-6 showing all basic tankage and piping systems. The supersonic diffuser cart and chamber section shown in the center foreground is designated as Test Stand H-4. Directly behind Test Stand H-4 within the superstructure is Test Stand H-4A with Test Stands H-5 and H-6, respectively, to the right of H-4A. Extending into the right foreground from the complex is the CFDTS ejector system. Partially hidden behind the right side of the complex is the LH₂ catch vessel and flare stack. Also, only partially visible behind the ejector system is the hot hydrogen heat exchanger.
- C 1164 131 View of the hot hydrogen heat exchanger with the test complex and ejector system in the left background and the 100,000 gallon LH₂ catch vessel shown in the right background.
- C 1164 256 View of the H-2 Control Room interior showing the control consoles in the foreground with the instrumentation and control bays extending across the center of the picture. Atop the recorders on the right are three closed circuit television viewing screens.
- C 1164 132 View of the Cryogenics Laboratory in Test Zone A showing the test bays as well as tankage and piping.